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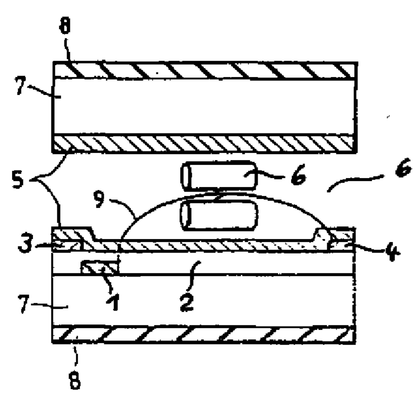
(54) Active matrix type liquid crystal display apparatus.

(57) The invention relates to novel liquid crystal compounds and active matrix type liquid crystal display apparatus having a group of electrodes (1,3,4) forming a matrix of pixels and active devices (14) each provided between the liquid crystal (6') and the orientation film (5). The electrodes are constructed so as to apply an electric field mainly parallel to the substrates (7) against the liquid crystal layer.

The resistivity of the liquid crystal (6') is lower than or equal to 1 x 10^{14} Ω•cm. The relation between the elasticity constant K_2 and the dielectric anisotropy $\Delta\epsilon$ satisfies the equation $K_2/\Delta\epsilon < 9.0 \times 10^{-8}$ [dyn].

FIG. 1(b)



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The present invention relates to novel liquid crystal compounds and active matrix type liquid crystal display apparatus, in which an electric field is applied mainly parallel to substrates and in which the broad visual field and the large numerical aperture are compatible.

In the conventional liquid crystal display apparatus, as for the electrodes for driving the liquid crystal layer, the electrodes are formed on the surface of two substrates, and transparent electrodes are used, the electrodes facing to each other. This is because what is used is a display method represented by a twisted nematic display method (TN method) in which the liquid crystal layer is driven by applying an electric field in the vertical direction to the surface of the substrate. On the other hand, as for the display method in which an electric field is applied in the direction almost parallel to the surface of the substrate, a display method using comb-type electrodes is disclosed in the Japanese Patent publication No. 63-21907 (1988) and USP 4,345,249. In this case, the electrodes are not necessarily selected to be transparent, but non-transparent and metallic electrodes with higher electric conductivity are used. However, in the above prior art, as for the display method in which the electric field is applied in the direction parallel to the surface of the electrode, (which is designated "horizontal electric field method"), specifically used in the active matrix drive mode, or as for the horizontal electric field method, the material property required to realize the high numerical aperture are not described in detail.

In the conventional active matrix type liquid crystal display apparatus, typically the twisted nematic method, the transparent electrode is used. It is, therefore, possible to make the numerical aperture relatively wider, which is the area that the light per the unit pixel passes through. However, in the horizontal electric field system, an opaque metal electrode is used. It is, therefore, impossible to realize a large numerical aperture. There is an essential problem in that the portion of the opaque electrode cannot be used as an area the light passes through. The brightness of the display apparatus depends upon the magnitude of the numerical aperture. Even if the intensity of background light is increased, the problem arises that the power consumption is increased extremely.

Accordingly, in order to realize a large numerical aperture in the horizontal electric field method, it is required to enlarge the gap between the electrodes. However, a new problem arises due to the enlargement of the gap. First, a disturbance of orientation occurs by the static electricity, because the volume of the liquid crystal decreases further. Generally, the electrodes in the horizontal electric field method are different in their configuration from those in the prior art. Therefore, the corresponding volume of the liquid crystal is not so large. If the volume becomes smaller by enlarging the gap between the electrodes, the liquid crystal is susceptible to be affected by the effect of static electricity. As a result, the disturbance of orientation due to static electricity increases. Secondly, if the gap between the electrodes becomes large, the problem arises in the horizontal electric field display method that a large drive voltage is required.

It is the object of the present invention to provide novel liquid crystal compounds and compositions and their use in liquid crystal display devices, and active matrix type liquid crystal display apparatus using the horizontal electric field method, in which the broad visual field and a large numerical aperture are compatible.

The above object is achieved according to the independent claims. The dependent claims relate to prefered embodiments.

In the present invention, the following means are used for solving the above mentioned problems and attaining the above objective.

[MEANS 1]

According to one aspect of the present invention, the display device of the present invention comprises: a pair of substrates at least one of which is transparent, a liquid crystal layer inserted between the substrates, an orientation film provided between the liquid crystal and at least one of the substrates on the inner side thereof, a scanning signal electrode, an image signal electrode, a pixel electrode and an active device each provided between the liquid crystal and the orientation film or the substrate 7, respectively, and polarization means provided on the outer side of the substrates, for changing an optical characteristic according to the orientation state of the liquid crystal, each of said electrodes being constructed so as to apply an electric field, mainly parallel to said substrates, against said liquid crystal layer, and being connected to external control means for optionally controlling the applied electric field according to the display pattern, wherein the electrode lies between at least two dielectric layers disposed above and below the electrode, and wherein the resistivity ρ of the liquid crystal is equal to or lower than $1 \cdot 10^{14}$ $\Omega \cdot$cm and preferably higher than or equal to 1×10^{9} $\Omega \cdot$cm and lower than or equal to 1×10^{13} $\Omega \cdot$ cm, i.e., satisfies the following equations:

$$\rho \leq 10^{14}\ \Omega \cdot \text{cm},$$

preferably:

$$1 \cdot 10^{9} \leq \rho \leq 1 \cdot 10^{13}\ \Omega \cdot \text{cm}.$$

[MEANS 2]

According to another aspect of the present invention, the display device of the present invention comprises: a pair of substrates at least one of which is transparent, a liquid crystal layer inserted between the substrates, an orientation film provided between the liquid crystal and at least one of the substrates on the inner side thereof, a scanning signal electrode, an image signal electrode, a pixel electrode and an active device each provided between the liquid crystal and the orientation film or the substrate 7, respectively, and polarization means provided on the outer side of the substrates, for changing an optical characteristic according to the orientation state of the liquid crystal, each of said electrodes being constructed so as to apply an electric field, mainly parallel to said substrates, against said liquid crystal layer, and being connected to external control means for optionally controlling the applied electric field according to the display pattern, wherein the ratio l/d of the gap l between said electrodes to the cell gap d is greater than or equal to 2.0, and the relation between the elasticity constant K_2 and the dielectric anisotropy $\Delta\epsilon$ satisfies the following equation (1):

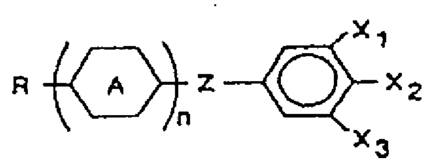
$$K_2/\Delta\epsilon < 9.0 \times 10^{-8}\ [\text{dyn}] \qquad (1).$$

[MEANS 3]

According to still another aspect of the present invention, in the means 2, the gap d between the substrates facing each other is less than or equal to 6 mm, the gap between the electrodes is more than or equal to 10 mm, and the drive voltage is lower than or equal to 5 V.

[MEANS 4]

According to a further aspect of the present invention, in the means 1 or 2, the liquid crystal composition includes a liquid crystal compound represented by the general formula I, in which cyano groups, trifluoromethyl groups, trifluoromethoxy groups or nitro groups are included as end groups:

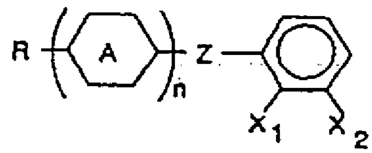


---- (I) .

In the formula I, X_1, X_2 and X_3 are fluoro, cyano, trifluoromethyl, trifluoromethoxy, nitro or hydrogen atoms; R is alkyl or alkoxy having 1 to 10 carbon atoms, which can be substituted, A is a cyclohexane ring, a benzene ring, a dioxane ring, a pyrimidine ring or a bicyclo[2.2.2]octane or -hexane ring; Z is a single bond, an ester bond, an ether bond, methylene or ethylene, and n is an integer of 1 or 2.

[MEANS 5]

According to a further aspect of the present invention, in the means 1 or 2, the liquid crystal composition includes a liquid crystal compound represented by the general formula II, in which cyano groups, trifluoromethyl groups, trifluoromethoxy group or nitro groups are included in a transverse axis of the liquid crystal molecule:



---- (II).

In the formula II, X_1 and X_2 are fluoro, cyano, trifluoromethyl, trifluoromethoxy, nitro or hydrogen atoms; R is alkyl or alkoxy having 1 to 10 carbon atoms which may be substituted, A is a cyclohexane ring, a benzene ring, a dioxane ring, a pyrimidine ring, or a bicyclo[2.2.2]octane or -hexane ring, Z is a single bond, an ester bond, an ether bond, methylene or ethylene, and n is an integer of 1 or 2.

[MEANS 6]

According to a further aspect of the present invention, in the means 1 or 2, when the dielectric anisotropy of the liquid crystal is positive, the rubbing angle is set to be more than or equal to 1 degree and less than or equal to 20 degrees relative to the vertical direction of the electric field, and when the dielectric anisotropy of the liquid crystal is negative, the rubbing angle is set to be more than or equal to 1 degree and less than or equal to 10 degrees relative to the direction of the electric field.

[MEANS 7]

According to a further aspect of the present invention, in the means 1 or 2, the common electrode is composed of a part of the display pixels, and an alternating current is applied to the common electrode.

[MEANS 8]

According to a further aspect of the present invention, in the means 1 or 2, the transmission axis of said polarizer is set to deviate 1 degree or more than 1 degree from the initial orientation direction of the liquid crystal to the rotation direction of the axis of the liquid crystal molecules due to the applied electric field.

In Fig. 2, the angle ϕ_P is defined by the polarization transmission axis 11, the angle ϕ_{LC} is defined by the liquid crystal molecule longitudinal axis (optical axis) 10 at the interface neighborhood, and the angle ϕ_R is defined by the condensive axis in a phase shifter plate inserted between two polarizers. The angles ϕ_P and ϕ_{LC} are expressed selectively in terms of ϕ_{P1}, ϕ_{P2}, ϕ_{LC1} and ϕ_{LC2} with regard to a pair of polarizers and a pair of liquid crystal interfaces.

Figs. 1(a) and (b) are side cross-sectional views showing the operation of the liquid crystal in the liquid crystal panel, and Figs. 1(c) and (d) show front views of them in the present invention. In Fig. 1, active devices are not shown. In addition, though a plurality of pixels are formed with stripe-shaped electrodes in the present invention, a partial view of only one single pixel is shown in Fig. 1. The side cross-sectional view when voltage is not applied is shown in Fig. 1(a), and the front view is shown in Fig. 1(c). The gap l between the electrode is indicated in Fig.1(c). The linear electrodes 3 and 4 are formed on the inner side of a pair of transparent substrates 7, and orientation films 5 are coated on the substrates 7 such that they are facing each other. Liquid crystal composite material 6 is inserted between the films, the gap d being indicated in Fig.1(a). The liquid crystal molecules 6 of linear shape are oriented so that the angle ϕ_{LC} between the longitudinal axis of the molecules and the longitudinal direction of the stripe-shaped electrode Y may be maintained to be an adequate angle such as $45° < |\phi_{LC}| < 90°$.

For the explanation below, the orientation direction of the liquid crystal molecules on the upper and lower interfaces is assumed to be parallel to each other, that is, $\phi_{LC1} = \phi_{LC2}$.

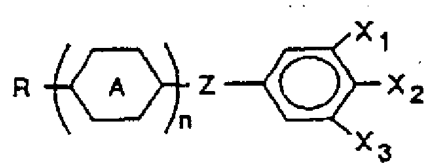
The dielectric anisotropy of the liquid crystal composite material is assumed to be positive. Next, when the electric field 9 is applied, as shown in Figs. 1(b) and 2, the longitudinal axis 10 of the liquid crystal molecules 6 is oriented in the direction of the electric field 9. By suitably arranging the polarizer 8 with its polarization axis, the optical transmission index can be modulated by applying and changing the applied electric field 9. Thus, a display operation for defining contrast is possible without transparent electrodes. Though the dielectric anisotropy of the liquid crystal composite material is assumed to be positive, it may be selected to be negative. In case of negative dielectric anisotropy, as for the initial orientation of the liquid crystal molecules, the angle ϕ_{LC} is maintained to be an adequate angle to the vertical direction to the longitudinal axis of the striped electrode such as $0° < |\phi_{LC}| < 45°$.

By providing the electrode between at least two dielectric layers disposed above and below the electrode, and by making the resistivity of the liquid crystal lower than or equal to 1 x 10^{13} Ω•cm, as described in the means 1, it is possible to increase the numerical aperture. The reason will be explained hereinafter. In the horizontal electric field mode, an opaque metal electrode is used. It is, therefore, impossible to realize numerical apertures larger than those of the prior art. The basic method for solving this problem is to enlarge the gap between the electrodes. However, a new problem may arise due to the enlargement of the gap. There occurs a disturbance of orientation by static electricity, because the volume of the liquid crystal is further decreased. The provision of an auxiliary capacitance to each of the pixels leads to a deterioration of the numerical aperture. However, if the resistance of the liquid crystal is low, the disturbance of the orientation due to the static electricity is small. Therefore, these are very effective means. By these means, the domain around the spacer beads is also improved. In the conventional active matrix type liquid crystal display apparatus, it is required to use liquid crystals with a high resistivity of at least 1 x 10^{13} Ω•cm, preferably, 1 x 10^{14} Ω•cm, in order to apply a sufficient voltage even during non-selected periods of time. In the horizontal electric field method, the dielectric except the liquid crystal, such as a glass or an insulation film, acts as a hold capacitance to obtain the voltage hold ratio necessary to work. By experiments, it has been found that even a liquid crystal with a resistivity of 1 x 10^{10} Ω•cm has a high voltage hold ratio (frame frequency: 60 Hz) of more than 90 %. However, as compared to the conventional method such as the TN method, the total capacitance including the capacitance of the liquid crystal and the hold capacitance is smaller in magnitude in the horizontal electric field method, and is susceptible to be affected by the effect of static electricity. It is not the static electricity but the increase of the drive voltage which is brought up by the enlargement of the gap between the electrodes.

As for the means for reducing the drive voltage, it has been found to be effective that, as described in the means 2 and 3, the relation between the dielectric anisotropy ($\Delta\epsilon$) of the liquid crystal composite material and the elasticity constant (K_2) of the twist should satisfy the equation $K_2/\Delta\epsilon < 9.0 \times 10^{-8}$ [dyn]. As the thickness of the electrode is less than that of the liquid crystal composite material layer in the ordinary horizontal electric field method, it is impossible to apply the electric field completely parallel to the interface between the liquid crystal and the orientation layer on the liquid crystal composite material layer. This insufficient horizontal electric field causes a reduction of the efficiency in the switching operation of the liquid crystal on the interface. By making the dielectric constant ϵ_{LC} of the liquid crystal larger than the dielectric constant ϵ_{AF} of the orientation layer, preferably making ϵ_{LC} twice as large than ϵ_{AF}, what can be applied to the liquid crystal is a horizontal electric field which is more parallel to the interface between the liquid crystal and the orientation layer. Based on a more intensive study in which the elasticity constant K_2 of the twist is modified to be smaller or the dielectric anisotropy of the liquid crystal is modified to be larger, when the ratio between the elasticity constant and the dielectric anisotropy is set to be 9.0×10^{-8} [dyn], and more preferably when this ratio is set to be 7.0×10^{-8} [dyn], a drive voltage of 5 V or less can be attained. A drive voltage of 5 V means that it is possible to achieve a display by using the 5 V voltage-tightness of a signal voltage driver.

A described in the means 4, by including chemical liquid crystal compounds represented by the general formula I, in which cyano groups, trifluoromethyl groups, trifluoromethoxy groups or nitro groups are included as end groups, effective liquid crystal apparatus may be achieved having a large numerical aperture. Namely, by decreasing the resistivity, the influence of static electricity can be prevented, and at the same time the drive voltage can be decreased. The decrease of the resistivity is further effective for small viscosity necessary for high-speed response.

Liquid crystals which do not have increased resistivity, such as through cyano groups, can be used for display devices because liquid crystals with lower resistivity show a high voltage hold ratio in the horizontal electric field method. Therefore, the applicability of this kind of liquid crystals is remarkably increased.



---- (I)

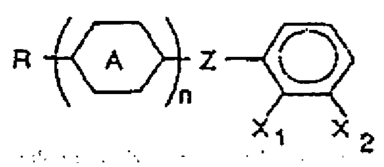
In the formula (I), X_1, X_2 and X_3 are fluoro groups, cyano groups, nitro groups or hydrogen atoms; R is alkyl or alkoxy having 1 to 10 carbon atoms which can be substituted; ring A is a cyclohexane ring, a benzene ring, a dioxane ring, a pyrimidine ring or a bicyclo[2.2.2]octane ring; Z is a single bond, an ester

bond, an ether bond, methylene or ethylene; and n is an integer of 1 or 2.

More concretely, examples for these compounds are: 1,2-dicyano-4-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-benzene; trans-4-propyl(3,4-dicyanobiphenyl-4'-yl)-cyclohexane; 2-(trans-4-propylcyclohexyl)-1-[trans-4-(3,4-dicyanophenyl)-cyclohexyl]-ethane; 3,4-dicyanophenyl-trans-4-pentylcyclohexylcarboxylate; 4-cyano-3-fluorophenyl-trans-4-propylcyclohexylcarboxylate; trans-4-heptyl-(3,5-difluoro-4-nitrophenyl)-cyclohexane; 2,6-difluoro-1-cyano-4-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-benzene; trans-4-propyl-(3,4,5-trifluorobiphenyl-4'-yl)-cyclohexane; 2-(trans-4-propylcyclohexyl)-1-[trans-4-(3,5-difluoro-4-nitrophenyl)-cyclohexyl]-ethane; 3,5-difluoro-4-nitrophenyl-trans-4-pentylcyclohexylcarboxylate; trans-4-heptyl-(3-fluoro-4-cyanophenyl)-cyclohexane; 2-fluoro-1-nitro-4-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-benzene; trans-4-propyl-(3-fluoro-4-cyanobiphenyl-4'-yl)-cyclohexane; 2-(trans-4-propylcyclohexyl)-1-[trans-4-(3-fluoro-4-nitrophenyl)-cyclohexyl]-ethane; 3-fluoro-4-cyanophenyl-trans-4-pentylcyclohexylcarboxylate; trans-4-heptyl-(4-cyanophenyl)-cyclohexane; 4-cyanophenyl-5-pentyl-1,3-pyrimidine; 4-cyano-3-fluorophenyl-5-propyl-1,3-pyrimidine; 4-cyanophenyl-4-pentyl-1,3-dioxane; 4-cyanophenyl-4-pentyl-bicyclo[2.2.2]octane. The present invention is not limited to the above compounds. The liquid crystal compounds having a fluoro group in the ortho position to a cyano group, represented by 4-cyano-3-fluorophenyl-trans-4-propylcyclohexylcarboxylate, is known to be materials which do not tend to form dimers leading to loss of the dipole momentum. As such liquid crystal compounds have larger dielectric constants and lower viscosities, it is effective to apply this kind of compounds for high-speed driving operation in the horizontal electric field method.

When using liquid crystals of negative dielectric anisotropy by including chemical liquid crystal compounds represented by the general formula (II), in which cyano groups, trifluoromethyl groups, trifluoromethoxy group or nitro groups are included as end groups as described in the means 5, we obtained effective liquid crystals leading to a large numerical aperture. Namely, by decreasing the resistivity, the static electricity influence can be prevented, and at the same time the drive voltage can be decreased. The decrease of the resistivity is further effective for small viscosity necessary for high-speed response.

Liquid crystals which do not have increased resistivity, such as through cyano groups, can be used for display devices because liquid crystals with lower resistivity show a high voltage hold ratio in the horizontal electric field method. Therefore, the applicability of this kind of liquid crystals is remarkably increased.



---- (II)

In the formula (II), X_1 and X_2 are fluoro atoms, cyano groups, nitro groups or hydrogen atoms; R is alkyl or alkoxy having 1 to 10 carbon atoms which can be substituted; ring A is a cyclohexane ring, a benzene ring, a dioxane ring, a pyrimidine ring, or a bicyclo[2.2.2]octane ring; Z is a single bond, an ester bond, an ether bond, methylene or ethylene; and n is an integer of 1 or 2.

Concrete examples for these compounds are: trans-4-heptyl-(2-cyano-3-fluorophenyl)-cyclohexane; 2-cyano-3-fluoro-4-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-benzene; trans-4-propyl-(2-cyano-3-fluorobiphenyl-4'-yl)-cyclohexane; 2-(trans-4-propylcyclohexyl)-1-[trans-4-(2-cyano-3-fluorophenyl)-cyclohexyl]-ethane; 2-cyano-3-fluorophenyl-trans-4-pentylcyclohexylcarboxylate; trans-4-heptyl-(2-fluoro-3-nitrophenyl)-cyclohexane; 2-fluoro-3-cyano-4-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-benzene; trans-4-propyl-(2-fluoro-3-nitrobiphenyl-4'-yl)-cyclohexane; 2-(trans-4-propylcyclohexyl)-1-[trans-4-(2-fluoro-3-nitrophenyl)-cyclohexyl]-ethane; 2-fluoro-3-cyanophenyl-trans-4-pentylcyclohexylcarboxylate; 2,3-dicyanophenyl-5-pentyl-1,3-pyrimidine; 2-cyano-3-fluorophenyl-5-propyl-1,3-pyrimidine; 2,3-dicyanophenyl-4-pentyl-1,3-dioxane; 2-cyano-3-fluorophenyl-4-pentylbicyclo[2.2.2]octane. The present invention is not limited to the above compounds.

As described in the means 6, when the dielectric anisotropy of the liquid crystal is positive, the rubbing angle is set to be more than or equal to 1 degree and less than or equal to 10 degrees, relative to the vertical direction of the electric field, and when the dielectric anisotropy of the liquid crystal is negative, the rubbing angle is set to be more than or equal to 1 degree and less than or equal to 10 degrees, relative to the direction of the electric field. This is another important means for reducing the drive voltage. As the angle between the axis of the liquid crystal molecules and the direction of the electric field becomes close to 90 degrees, the voltage at the maximum transmission factor shifts to the low voltage side. Further a non-select voltage can be set to the high voltage side, because the threshold voltage of the response to the

electric field shifts to the high voltage side. Accordingly, it is possible to reduce the width of the drive voltage. Fig. 9 shows a typical example thereof. Therefore, it is desirable that the rubbing angle is as small as possible, as long as any domains do not occur.

In addition, it is possible to further reduce the drive voltage by applying an alternating current to the common electrode as described in the means 7, after having carried out these means.

Furthermore, we found that the means 8 are also effective to reduce the width of the drive voltage as shown in Fig. 10, in which the transmission axis of a polarizing plate deviates by more than 1 degree from the initial orientation direction.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a view illustrating the operation of the liquid crystal using the horizontal electric field method.

Fig. 2 is an illustrative view of the definition of the rubbing direction and the axis direction of the polarizer.

FIG. 3 is a view showing an example of the electrode configuration in the unit pixel of the liquid crystal display apparatus.

FIG. 4 is a view showing another example of the electrode configuration in the unit pixel of the liquid crystal display apparatus.

FIG. 5 is a typical example of the configuration of a color filter substrate.

FIG. 6 is a diagrammatic view showing a TFT circuit in the liquid crystal display apparatus according to the present invention.

Fig.7 is an example of the waveform of alternating current applied to the common electrode.

FIG.8 is a graph showing the result of experiments on the voltage hold ratio in the liquid crystal display apparatus according to the present invention.

FIG. 9 is a graph showing the variation of the width of drive voltage in the rubbing direction.

FIG. 10 is a graph showing the variation of the voltage-transmittance characteristic caused by the variation of the axis direction of the polarizer.

FIG. 11 is a graph showing the voltage-transmittance characteristic.

FIG. 12 is a graph showing the voltage-transmittance characteristic.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiments of the present invention will be explained in detail.

[Embodiment 1]

Two transparent glass substrates are used, which are of 1.1 mm in thickness, and the surface of which is polished. After forming thin film transistors on one of the substrates, the orientation film is formed thereon, which also acts as an insulation film. A polyimide is used as the orientation film in this embodiment. A rubbing-processing is performed on the polyimide film in order to orient the liquid crystal. The polyimide and rubbing processings are performed also on the other substrate. The individual rubbing directions of a pair of substrates are parallel to each other, and have an angle of 75° ($\phi_{LC1} = \phi_{LC2} = 75°$) with respect to the direction of the applied electric field. A nematic liquid crystal composition is sandwiched between these substrates, having a dielectric anisotropy $\underline{\Delta\epsilon}$ of +7.3 and a refractive index anisotropy Δn of 0.074 (589 nm, 20°). A gap d is achieved by distributing polymer beads between the substrates, and the space of the gap is 4.0 μm. Thus, d· Δn is 0.296 μm. The panel is sandwiched with a pair of polarizers (G1220DU, made by Nitto Electric Co.), and the polarization transmission axis of one polarizer is set to $\phi_{P1} = 75°$, and the polarization transmission axis of the other polarizer is set to intersect perpendicularly with the former polarization transmission axis, which means $\phi_{P2} = -15°$. With this geometrical configuration, the normally-close characteristic of the display pixel can be established, that is, the display pixel is in a dark state at a low voltage (V_{OFF}), and is in a bright state at a high voltage (V_{ON}).

Fig. 3 shows the configurations of a thin film transistor 14 and all kinds of electrodes. Fig.3 (a) is a front view seen from the direction perpendicular to the surface of the substrate. Fig.3 (b) and (c) are sectional side elevations. The thin film transistor 14 representing the active device comprises a pixel electrode (source electrode) 4, a signal electrode (drain electrode) 3, scanning electrode (gate electrode) 12, and amorphous silicon 13. Common electrodes 1 and the scanning electrode 12, and the signal electrode 3 and the pixel electrode 4, respectively, are a part of the pattern made by the same metal layer. A capacitor 16 is made by sandwitching a gate insulation film 2 with the pixel electrode 4 and the common electrodes 1 at an

area (shown by the dotted line in Fig.1) between two common electrodes. In Fig.3(a), the pixel electrode 4 is disposed between two common electrodes 1. the pitch of the pixel electrode is 69 μm in a horizontal direction i.e. between signal wiring electrodes, and 207 μm in a vertical direction i.e. between scanning wiring electrodes. The width of the electrode is taken widely in order to avoid a wiring defect, in the wiring electrode extending over a plurality of electrodes, the scanning electrode, the signal electrode, or the common electrode wiring portion (the portion extending in a direction (in a horizontal direction in Fig.3) parallel to the scanning wiring electrode). More concretely, the width of the electrode is taken to 10 μm. The width of the electrode is taken a little bit narrowly in order to increase a numerical aperture, in the pixel electrode formed independently every pixel and the longitudinally extending portion of the signal wiring electrode of the common electrode. More concretely, the width of the electrode is taken to 5 μm and 8 μm, respectively. The possibility of breaking of wire become higher, because the width of electrode was decreased. However, the breaking of wire ends in a partial defect, and does not end in a line defect. In addition, in order to increase the numerical aperture as high as possible, a portion of the common electrode and a portion of the signal electrode are provided one over the other, in which an insulation film is inserted between those electrodes, and the width of the piled portion is 1 μm. Thereby, it is not necessary to provide the black matrix 22 parallel to the signal wiring. As a result, the present invention adopts the black matrix configuration as shown in Fig.3(c), in which only the light in the direction of the scanning wiring electrode is prevented. As a result, the 44.0% high numerical aperture is obtained, in which the gap between the common electrode add the pixel electrode is 20 μm, the length in the longitudinal direction of the opening is 157 μm, and the number of the pixel formed by 320 signal wiring electrodes and 160 wiring electrodes is 320 x 160.

The resistivity of the liquid crystal is 7.6 x 10^{12}, and the undesirable conditions of orientation due to the static electricity do not occur. The active matrix type liquid crystal display apparatus both with the broad visual field and the large numerical aperture is established, in which the inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 2]

The structure in the embodiment 2 is identical to that of the embodiment 1 excluding the following features.

The material used for the liquid crystal compound is prepared by adding the 5 weight % of 4-cyano-3-fluorophenyl-trans-4-propylcyclohexylcarboxylate into the liquid crystal of the embodiment 1. Where, the weight % represents hereinafter the ratio to the total weight.

The resistivity of the liquid crystal is 7.6 x 10^{12} Ω•cm, and the undesirable conditions of orientation due to the static electricity do not occur. The active matrix type liquid crystal display apparatus both with the broad visual field and the large numerical aperture is established, in which the inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 3]

The structure in the embodiment 3 is identical to that of the embodiment 1 excluding the following features.

The material used for the liquid crystal compound is prepared by adding the 7 weight % of 3, 4-dicyanophenyl-trans-4-pentylcyclocarboxylate into the liquid crystal composite of the embodiment 1..

The resistivity of the liquid crystal is 3.3 x 10^{11} Ω•cm, and the undesirable condition of orientation due to the static electricity do not occur. As a result, the active matrix type liquid crystal display apparatus both with the broad visual field and the large numerical aperture is established, in which the inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 4]

The structure in the embodiment 4 is identical to that of the embodiment 1 excluding the following features.

The material used for the liquid crystal compound is prepared by adding the 10 weight % of 4-trifluoromethoxyl-3, 5-difluorophenyl-trans-4-bentylcyclohexylcalboxylate into the liquid crystal compound

having 4-cyano-3-fluorophenyl-trans-4-ethylphenylcarboxylate, 1-[4-(3, 4, 5-trifluorophenyl) cyclohexyl]-2-(4-methylcyclohexyl) ethane, 4-cyano-3-fluorophenyl-4-(4-propylcyclohexyl)-phenylcarboxylate and so on as a representative compound.

The resistivity of the liquid crystal is 2.4 x 10^{10} Ω•cm, and the undesirable conditions of orientation due to the static electricity do not occur. The relation between the elasticity constant K_2 and the dielectric anisotropy $\Delta\epsilon$, is made to be 8.5 x 10^{-8} Ω•cm. Further, the drive voltage can be established to be 5V or less. As a result, the active matrix type liquid crystal display apparatus both with the broad visual field and the large numerical aperture is established, in which the inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 5]

The structure in the embodiment 5 is identical to that of the embodiment 1 excluding the following features.

The material used for the liquid crystal compound is prepared by adding the 20 weight % of 4-cyano-3, 5-difluorophenyl-trans-4-bentylcyclohexylcarboxylate into the liquid crystal compound having 4-cyano-3-fluorophenyl-trans-4-ethylphenylcarboxylate, 1-[4-(3, 4, 5-trifluorophenyl) cyclohexyl]-2-(4-methylcyclohexyl) ethane, 4-cyano-3-trifluoromethyl-5-fluorophenyl-4-(4-propylcyclohexyl) phenylcarboxylate and so on as a representative compound.

The resistivity of the liquid crystal is 9.3 x 10^{9} Ω•cm, and the undesirable conditions of orientation due to the static electricity do not occur. The relation between the elasticity constant K_2 and the dielectric anisotropy $\Delta\epsilon$, is made to be 5.4 x 10^{-8} Ω•cm. Further, the drive voltage can be established to be 5V or less. As a result, the active matrix type liquid crystal display apparatus both with the broad visual field and the large numerical aperture is established, in which the inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 6]

The structure in the embodiment 5 is identical to that of the embodiment 1 excluding the following features.

Fig. 4 shows the configurations of thin film transistors 14 and all kinds of electrodes, in more detail, it shows a front view seen from the direction perpendicular to the surface of the substrate of Fig.4 and sectional side elevations each taken along the lines A-A' and B-B', respectively. The thin film transistor 14 comprises a pixel electrode (source electrode) 4, a signal electrode (drain electrode) 3, scanning electrode (gate electrode) 12, and amorphous silicon 13 (cf Fig. 3(a)). Common electrodes 1 and the scanning electrode 12, and the signal electrode 3 and the pixel electrode 4, respectively, are a part of the pattern made by the same metal layer. A capacitor 16 is made by sandwitching a gate insulation film 2 with the pixel electrode 4 and the common electrodes 1 at an area (shown by the dotted line in Fig.1) between two common electrodes. In the front view, the pixel electrode is disposed among three common electrodes 1. the pitch of the pixel electrode is 100 µm in a horizontal direction i.e. between signal wiring electrodes, and 300 µm in a vertical direction i.e. between scanning wiring electrodes. The width of the electrode is taken widely in order to avoid a wiring defect in the wiring electrode extending over a plurality of electrodes, the scanning electrode 12, the signal electrode 13, or the common electrode wiring portion (the portion extending in a direction (in a horizontal direction in Fig.3) parallel to the scanning wiring electrode). More concretely, the width of the electrodes are taken to 10 µm, 8 µm and 8 µm, respectively. While, the width of the pixel electrode formed independently every pixel and that of the longitudinally extending portion of the signal wiring electrode of the common electrode are taken a little bit narrowly. More concretely, these width are taken to 5 µm and 6 µm, respectively. The possibility of the breaking of wire become higher, because the width of electrode was decreased. However, the breaking of wire ends in a partial defect, and does not end in a line defect. In addition, the common electrode and the signal electrode is spaced by using the insulation film, in which the spacing is 2 µm in thickness. The black matrix configuration and a color filter are provided on the opposite substrate side as shown in Fig.5. The gap between the common electrode and the pixel electrode is 20 µm, and the length in the longitudinal direction of the opening is 157 µm. As a result, the number of pixels formed by 640 signal wiring electrodes and 480 wiring electrodes is 320 x 160.

The nematic liquid crystal composite is sandwitched between the substrates, which includes 10 weight % of 3-cyano-4-trifluoro-methoxy-5-fluorophenyl-trans-4-ethylcyclohexylcarboxylate, and in which the dielectric anisotropy $\Delta\epsilon$, is + 8.9, the refractive index anisotropy is Δn is 0.08 (589 nm, 20°).

The resistivity of the liquid crystal is 8.1×10^{12} Ω•cm, and the undesirable conditions of orientation due to the static electricity do not occur. As a result, the active matrix type liquid crystal display apparatus both with the broad visual field and the large numerical aperture is established, in which the inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 7]

The structure in the embodiment 7 is identical to that of the embodiment 6 excluding the following features.

The material used for the liquid crystal compound is prepared by adding the 10 weight % of 4-cyano-3, 5-difluorophenyl-trans-4-propylcyclohexylcarboxylate into the liquid crystal of the embodiment 6.

The resistivity of the liquid crystal is 2.2×10^{10} Ω•cm, and the undesirable conditions of orientation due to the static electricity do not occur. The relation between the elasticity constant K2 and the dielectric anisotropy $\Delta\epsilon$, is made to be 4.9×10^{-8} Ω•cm Further, the drive voltage can be established to be 5V or less. As a result, the active matrix type liquid crystal display apparatus both with the broad visual field and the large numerical aperture is established, in which the inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 8]

The structure in the embodiment 8 is identical to that of the embodiment 6 excluding the following features.

The material used for the liquid crystal compound is prepared by adding the 20 weight % of 4-cyano-3, 5-difluorophenyl-trans-4-probylcyclohexylcalboxylate into the liquid crystal composite of the embodiment 6.

The resistivity of the liquid crystal is 6.2×10^{10} Ω•cm, and the undesirable conditions of orientation due to the static electricity do not occur. The relation between the elasticity constant K_2 and the dielectric anisotropy, $\Delta\epsilon$, is made to be 2.9×10^{-8} Ω•cm. Further, the drive voltage can be established to be 5V or less. As a result, the active matrix type liquid crystal display apparatus both with the broad visual field and the large numerical aperture is established, in which the inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 9]

The structure in the embodiment 9 is identical to that of the embodiment 6 excluding the following features.

The material used for the liquid crystal compound is prepared by adding the 10 weight % of 3-cyano-4-trifluoromethoxy-5-fluorophenyl-trans-4-ethylcyclohexylcarboxylate into the liquid crystal composite of the embodiment 6.

The resistivity of the liquid crystal is 8.8×10^{9} Ω•cm, and the undesirable conditions of orientation due to the static electricity do not occur. The relation between the elasticity constant K_2 and the dielectric anisotropy $\Delta\epsilon$, is made to be 2.3×10^{-8} Ω•cm. Further, the drive voltage can be established to be 5V or less. As a result, the active matrix type liquid crystal display apparatus both with the broad visual field and the large numerical aperture is established, in which the inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 10]

The structure in the embodiment 10 is identical to that of the embodiment 1 excluding the following features.

The individual rubbing direction of the orientation film of the pair of substrates is parallel to each other, and has an angle 15° ($\phi_{LC1} = \phi_{LC2} = 15°$) with respect to the direction in which the applied electric field is extended. A nematic liquid crystal composite is sandwitched with these substarates, of which the dielectric constant anistropy $\Delta\epsilon$ is - 3.3 and the refractive index anistropy Δn is 0.074 (589nm, 20°). The material used here is the liquid crystal compound in which 4 weight % of 3-cyano-2-fluorophenyl-trans-4-pentylcyclohexylcarboxylate is added to the nematic liquid crystal composite.

The resistivity of the liquid crystal is 8.6×10^{11} Ω•cm, and the undesirable conditions of orientation due to the static electricity do not occur. As a result, the active matrix type liquid crystal display apparatus both

with the broad visual field and the large numerical aperture is established, in which the inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 11]

The structure in the embodiment 11 is identical to that of the embodiment 6 excluding the following features.

The 10 weight % of 2-(trans-4-propylcyclohexyl)-1-[trans-4-(2, 3-dicyanophenyl)cyclohexyl] ethane is added into a nematic liquid crystal composite, in which the dielectric constant anistropy $\Delta\epsilon$ is -3.3 and the refractive index anistropy Δn is 0.074 (589nm, 20°).

The resistivity of the liquid crystal is 7.2×10^{10} Ω•cm, and the undesirable conditions of orientation due to the static electricity do not occur. As a result, the active matrix type liquid crystal display apparatus both with the broad visual field and the large numerical aperture is established, in which the invention of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 12)

The structure in the embodiment 12 is identical to that of the embodiment 6 excluding the following features.

The individual rubbing direction of a pair of substrates is parallel to each other, and has an angle 85° (ϕ_{LC1} = ϕ_{LC2} = 85°) with respect to the direction in which the applied electric field is extended, the polarization transmission axis of one polarizer is set to ϕ_{P1} = 85°, and the polarization transmission axis of the other polarizer is set to intersect perpendicularly with the former polarization transmission axis, which means ϕ_{P2} = -5°. With this geometrical configuration, the normally-close characteristic of the display pixel can be established, that is, the display pixel is in a dark state at a low voltage (VO_{OFF}), and is in a bright state at a high voltage (V_{ON}).

The voltage-transmittance characteristic of this active matrix type liquid crystal apparatus indicates that of Fig.11, in which V_{OFF} can be set to 2.1 V and V_{ON} can be set to 6.8 V. Therefore, the width of the drive voltage can be set to 4,7 V. As a result, an active matrix type liquid crystal display apparatus both with the broad visual field and the large numerical aperture is established, in which the inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 13]

The structure in the embodiment 13 is identical to that of the embodiment 11 excluding the following features.

The individual rubbing direction of a pair of substrates is parallel to each other, and has an angle 5° (ϕ_{LC1} = ϕ_{LC2} = 5°) with respect to the direction in which the applied electric field is extended. the polarization transmission axis of one polarizer is set to ϕ_{P1} = 5°, and the polarization transmission axis of the other polarizer is set to intersect perpendicularly with the former polarization transmission axis, which means ϕ_{P2} = -85°. With this geometrical configuration, the normally-close characteristic of the display pixel can be established, that is, the display pixel is in a dark state at a low voltage (V_{OFF}), and is in a bright state at a high voltage (V_{ON}).

The voltage-transmittance characteristic of this active matrix type liquid crystal apparatus indicates that of Fig.11, in which V_{OFF} can be set to 4.0 V and V_{ON} can be set to 8.8 V. Therfore, the width of drive voltage can be set to 4.8 V. As a result, the active matrix type liquid crystal display apparatus both with the broad visual field and the large numerical aperture is established, in which the inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

[Embodiment 14]

The structure in the embodiment 14 is identical to that of the embodiment 12 excluding the following features.

The common electrode is made like the following in the same way as Fig.6, in order to apply an alternating current thereto. Each scanning electrode 12 and each signal electrode 3 are connected to a scanning electrode drive circuit 18 and a signal electrode drive circuit 19, respectively. Further, the common electrode 1 is connected to a common electrode drive circuit 20. A signal waveform with an information is applied to the signal electrode 3. A scanning waveform in synchronism with the signal waveform is applied to the scanning electrode 12. The information signal is transferred from the signal electrode 3 through a thin film transistor 14 to the pixel electrode 4, whereby the voltage produced between the pixel electrode and the common electrode 1 is applied to a portion of the liquid crystal. In the present invention, a voltage waveform is also applied to the common electrode. Therefore, a voltage in which that of the common electrode is added is applied to the portion of the liquid crystal. Fig.7 shows those voltage waveforms applied to each of the wiring electrodes, where the amplitudes of the voltage waveforms in Fig.7 are set as follows.

$V_{D-CENTER}$ = 14.0 V, V_{GH} = 28.0 V, V_{GL} = 0 V,

V_{DH} = 16.4 V, V_{DL} = 11.4 V, V_{CH} = 15.1 V, V_{CL} = 9.1 V. The V_{ON} and V_{OFF} of Fig.11 are 2.1 volts and 6.8 volts, respectively. As a result, the higher contrast ratio is obtained, which means 150. In Fig.11, V_{DP-P}, V_{SP-P}, and V_{CP-P}, represent peak-to-peak of the signal voltage, the source voltage, and the common voltage, respectively.

In the present embodiment, the amplitude of the drive voltage waveform V_{DP-P} (= V_{DH} - V_{DL}) is very low value, 4.7 volts, which is supplied to the signal wiring electrode. Accordingly, a relatively cheap driver can be used, and it becomes possible to reduce the production cost.

[Embodiment 15]

The structure in the embodiment 15 is identical to that of the embodiment 13 excluding the following features.

In the same way as the Embodiment 14. the alternative current is applied to the common electrode, and the display apparatus is drived. Accordingly, a relatively cheap diver can be used, and it becomes possible to reduce the production cost.

[Embodiment 16]

The structure in the embodiment 16 is identical to that of the embodiment 14 excluding the following features.

The transmission axis of the polarizer is set so as to have an angle 10° with respect to the rubbing direction, namely, ϕ_{P1} = 75° and ϕ_{P2} = -15°. Fig.12 shows the relationship between the voltage-transmittance characteristic and the drive waveform obtained in the above structure. in Fig.12, V_{DP-P}, V_{SP-P}, and V_{CP-P}, represent peak-to-peak of the signal voltage, the source voltage, and the common voltage.

The common electrode is made like the following in the same way as the Embodiment 9, in order to apply an alternating current thereto. Each scanning electrode 12 and each signal electrode 3 are connected to a scanning electrode drive circuit 18 and a signal electrode drive circuit 19, respectively. Further, the common electrode 1 is connected to a common electrode drive circuit 20 (see Fig.6). A signal waveform with an information is applied to the signal electrode 3. A scanning waveform in synchronism with the signal waveform is applied to the scanning electrode 12. The information signal is transferred from the signal electrode 3 through a thin film transistor 14 to the pixel electrode 4, whereby the voltage produced between the pixel electrode and the common electrode 1 is applied to a portion of the liquid crystal. In the present invention, a voltage waveform is also applied to the common electrode. Therefore, a voltage in which that of the common electrode is added is applied to the portion of the liquid crystal. Fig.7 shows those voltage waveforms applied to each of the wiring electrodes, where the amplitudes of the voltage waveforms in Fig.7 are set as follows.

$V_{D-CENTER}$ = 14.0 V, V_{GH} = 28.0 V, V_{GL} = 0 V,

V_{DH} = 15.1 V, V_{DL} = 12.9 V, V_{CH} = 20.4 V, V_{CL} = 4.39 V.

As a result, the plunge voltage $\Delta V_{GS}(+1)$, $\Delta V_{GS}(-1)$ produced by the parasitic capacitance between the gate electrode and the source electrode, the voltage V_S applied over the pixel electrode and the voltage V_{LC} applied over the liquid crystal are shown in the following Table. The unit of voltage is hereinafter taken as a volt.

TABLE 1

DISPLAY STATES	$\Delta V_{GS}(+)$	$\Delta V_{GS}(-)$	V_{SH}	V_{SL}	V_{LCH}	V_{LCL}	V_{rms}
BRIGHTNESS	+1.76	-1.64	+11.14	-13.46	+9.24	-9.07	9.16
DARKNESS	+1.47	-1.57	+13.63	-11.33	+6.75	-6.94	6.85

The V_{ON} and V_{OFF} of Fig.12 are 9.16 volts and 6.85 volts, respectively. As a result, the sufficiently high contrast ratio of 100 is obtained.

In the present embodiment, the amplitude of the drive voltage waveform V_{DP-P} (= V_{DH} - V_{DL}) has a very low value of 2.2 volts, which is supplied to the signal wiring electrode.

[Embodiment 17]

The structure in the embodiment 17 is identical to that of the embodiment 15 excluding the following features.

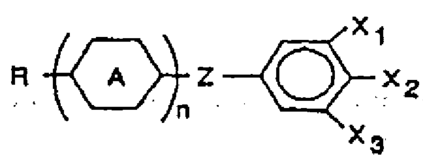
The transmission axis of the polarizer is set so as to have an angle 10° with respect to the rubbing direction, namely, ϕ_{P1} = 15° and ϕ_{P2} = -75°. As a result, the V_{ON} and V_{OFF} are 17.4 volts and 14.2 volts, respectively. As a result, a sufficiently high contrast ratio 100 is obtained.

In the present embodiment, the amplitude of the drive voltage waveform V_{DP-P} (= V_{DH} - V_{DL}) is a very low value, 3.2 volts, which is supplied to the signal wiring electrode.

While in the embodiments of this invention, the specific liquid crystal conposites and its compounds are used, it will easily be understood that other liquid crystal compositions and compounds can be used. The structure of the pixels is also not limited to that of the above-described embodiments according to the present invention.

Claims

1. Liquid crystal compounds of the general formula I,



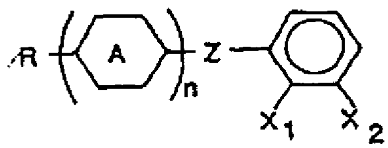
(I)

wherein are:
X_1, X_2 and X_3 fluoro, cyano, trifluoromethyl, trifluoromethoxy, nitro or a hydrogen atom,
R C_{1-10}-alkyl or C_{1-10}-alkoxy, which may be substituted, A a cyclohexane ring, a benzene ring, a dioxane ring, a pyrimidine ring or a bicyclo[2.2.2]octane ring,
Z a single bond, an ester bond, an ether bond, methylene or ethylene,
and
n 1 or 2.

2. Liquid crystal compounds of formula I, selected from 1,2-dicyano-4-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-benzene; trans-4-propyl(3,4-dicyanobiphenyl-4'-yl)-cyclohexane; 2-(trans-4-propyl-cyclohexyl)-1-[trans-4-(3,4-dicyanophenyl)-cyclohexyl]-ethane; 3,4-dicyanophenyl-trans-4-pentyl-cyclohexylcarboxylate; 4-cyano-3-fluorophenyl-trans-4-propylcyclohexylcarboxylate; trans-4-heptyl-(3,5-difluoro-4-nitrophenyl)-cyclohexane; 2,6-difluoro-1-cyano-4-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-benzene; trans-4-propyl-(3,4,5-trifluorobiphenyl-4'-yl)-cyclohexane; 2-(trans-4-propyl-cyclohexyl)-1-[trans-4-(3,5-difluoro-4-nitrophenyl)-cyclohexyl]-ethane; 3,5-difluoro-4-nitrophenyl-trans-4-pentylcyclohexylcarboxylate; trans-4-heptyl-(3-fluoro-4-cyanophenyl)-cyclohexane; 2-fluoro-1-nitro-4-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-benzene; trans-4-propyl-(3-fluoro-4-cyanobiphenyl-4'-yl)-cyclohexane; 2-(trans-4-propylcyclohexyl)-1-[trans-4-(3-fluoro-4-nitrophenyl)-cyclohexyl]-ethane; 3-fluoro-4-cyanophenyl-trans-4-pentylcyclohexylcarboxylate; trans-4-heptyl-(4-cyanophenyl)-cyclohexane; 4-cyanophenyl-5-pentyl-1,3-pyrimidine; 4-cyano-3-fluorophenyl-5-propyl-1,3-pyrimidine; 4-cyanophenyl-

4-pentyl-1,3-dioxane; 4-cyanophenyl-4-pentyl-bicyclo[2.2.2]octane.

3. Liquid crystal compounds of the general formula II,



---- (II),

wherein are:
X_1 and X_2 fluoro, cyano, trifluoromethyl, trifluoromethoxy, nitro or a hydrogen atom,
R C_{1-10}-alkyl or C_{1-10}-alkoxy, which may be substituted, A a cyclohexane ring, a benzene ring, a dioxane ring, a pyrimidine ring or a bicyclo[2.2.2]octane ring,
Z a single bond, an ester bond, an ether bond, methylene or ethylene,
and
n 1 or 2.

4. Liquid crystal compounds of formula II, selected from trans-4-heptyl-(2-cyano-3-fluorophenyl)-cyclohexane; 2-cyano-3-fluoro-4-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-benzene; trans-4-propyl-(2-cyano-3-fluorobiphenyl-4'-yl)-cyclohexane; 2-(trans-4-propylcyclohexyl)-1-[trans-4-(2-cyano-3-fluorophenyl)-cyclohexyl]-ethane; 2-cyano-3-fluorophenyl-trans-4-pentylcyclohexylcarboxylate; trans-4-heptyl-(2-fluoro-3-nitrophenyl)-cyclohexane; 2-fluoro-3-cyano-4-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-benzene; trans-4-propyl-(2-fluoro-3-nitrobiphenyl-4'-yl)-cyclohexane; 2-(trans-4-propylcyclohexyl)-1-[trans-4-(2-fluoro-3-nitrophenyl)-cyclohexyl]-ethane; 2-fluoro-3-cyanophenyl-trans-4-pentylcyclohexylcarboxylate; 2,3-dicyanophenyl-5-pentyl-1,3-pyrimidine; 2-cyano-3-fluorophenyl-5-propyl-1,3-pyrimidine; 2,3-dicyanophenyl-4-pentyl-1,3-dioxane; 2-cyano-3-fluorophenyl-4-pentyl-bicyclo[2.2.2]octane.

5. Liquid crystal compositions, comprising one or more liquid crystal compounds of formula I according to claim 1 or 2 and/or one or more liquid crystal compounds of formula II according to claim 3 or 4.

6. Use of the liquid crystal compounds of the general formulae I and II according to claims 1 to 4 or use of the liquid crystal compositions according to claim 5 for manufacturing or in liquid crystal display devices, particularly of the active matrix type, and preferably of the horizontal electric field type.

7. Active matrix type liquid crystal display device (21), comprising a pair of substrates (7), at least one of which is transparent, a liquid crystal layer (6') inserted between the substrates (7), an orientation film (5) provided between the liquid crystal layer (6') and at least one substrate (7) on the inner side thereof, a scanning signal electrode (3), an image signal electrode, a pixel electrode (4) and an active device (14),
and polarization means (8) provided on the outer side of the substrates (7) for changing an optical characteristic according to the orientation state of the liquid crystal; each of said electrodes being constructed so as to apply an electric field, mainly parallel to the substrates (7), against the liquid crystal layer (6'), and being connected to external control means (17, 18, 19, 20) optionally controlling the applied electric field according to the display pattern,
wherein the electrode lies between at least two dielectric layers disposed above and below the electrode, and wherein the resistivity ρ of the liquid crystal is equal to or lower than 1×10^{14} $\Omega \cdot cm$ and preferably higher than or equal to $1 \cdot 10^{9}$ $\Omega \cdot cm$ and lower than or equal to $1 \cdot 10^{13}$ $\Omega \cdot cm$.

8. Active matrix type liquid crystal display device (21) comprising a pair of substrates (7), at least one of which is transparent, a liquid crystal layer (6') inserted between the substrates (7), an orientation film (5) provided between the liquid crystal layer (6') and at least one substrate (7) on the inner side thereof, a scanning signal electrode (3), an image signal electrode, a pixel electrode (4) and an active device (14),
and polarization means (8) provided on the outer side of the substrates (7), for changing an optical characteristic according to the orientation state of the liquid crystal; each of said electrodes being constructed so as to apply an electric field, mainly parallel to the substrates (7), against the liquid

crystal layer (6'), and being connected to external control means (17, 18, 19, 20) for optionally controlling the applied electric field according to the display pattern,
optionally according to claim 7,
wherein the ratio l/d of the gap l between the electrodes to the cell gap d is greater than or equal to 2.0, and the relation between the elasticity constant K_2 and the dielectric anisotropy $\delta\epsilon$ satisfies the following equation (1):

$$K_2/\Delta\epsilon < 9.0 \cdot 10^{-8}\ [\mathrm{dyn}] \qquad (1).$$

9. Active matrix type liquid crystal display device according to claim 8,
wherein the gap d between the substrates facing each other is less than or equal to 6 mm, the gap l between the electrodes is more than or equal to 10 mm, and the drive voltage is lower than or equal to 5 V.

10. Active matrix type liquid crystal display device according to claims 7, 8 and/or 9, comprising a liquid crystal compound of formula I according to claim 1 or 2 and/or a liquid crystal compound of formula II according to claim 3 or 4, or a liquid crystal composition according to claim 5.

11. Active matrix type liquid crystal display device according to one or more of claims 7 to 10, wherein, when the dielectric anisotropy of the liquid crystal is positive, the rubbing angle is set to be more than or equal to 1 degree and less than or equal to 20 degrees relative to the vertical direction of the electric field, and when the dielectric anisotropy of the liquid crystal is negative, the rubbing angle is set to be more than or equal to 1 degree and less than or equal to 10 degrees relative to the direction of the electric field.

12. Active matrix type liquid crystal display device according to one or more of claims 7 to 11, wherein the common electrode (1) is composed of a part of the display pixels; and the device is designed for an alternating current to be applied to the common electrode (1).

13. Active matrix type liquid crystal display device according to one or more of claims 7 to 12, wherein the transmission axis of the polarizer (8) is set to deviate 1 degree or more than 1 degree from the initial orientation direction of the liquid crystal to the rotation direction of the axis (10) of the liquid crystal molecules due to an applied electric field (9).

FIG. 1(a)

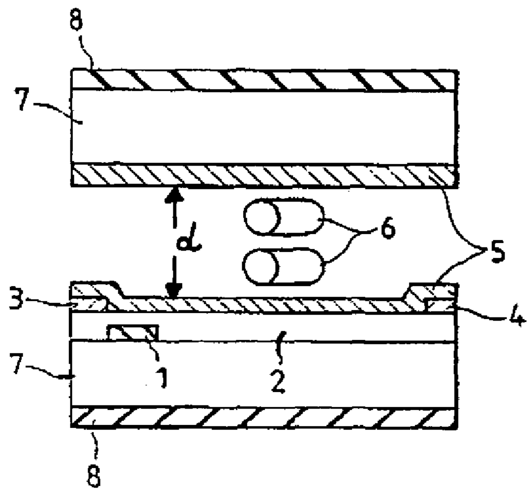


FIG. 1(b)

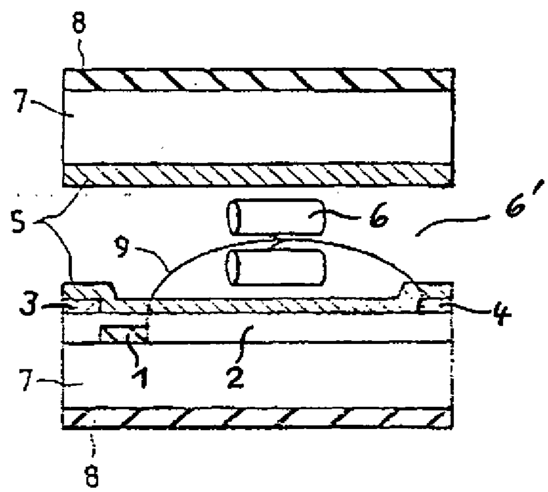


FIG. 1(c)

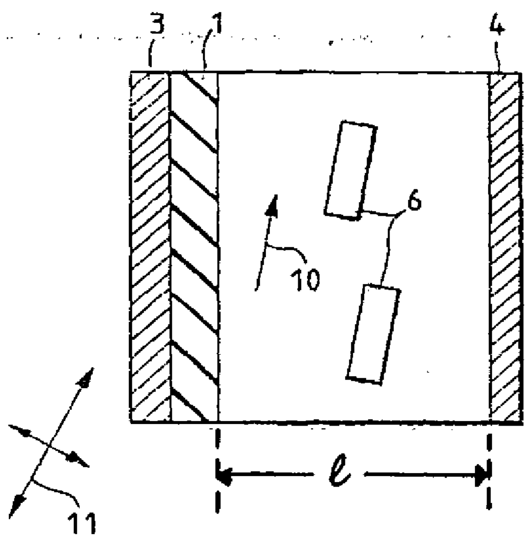


FIG. 1(d)

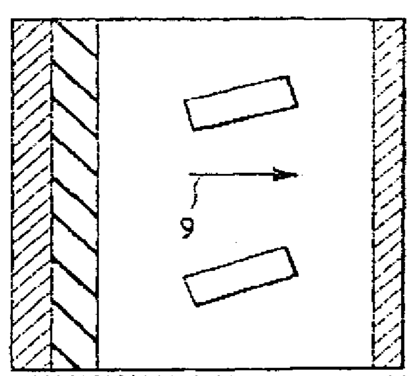


FIG. 2

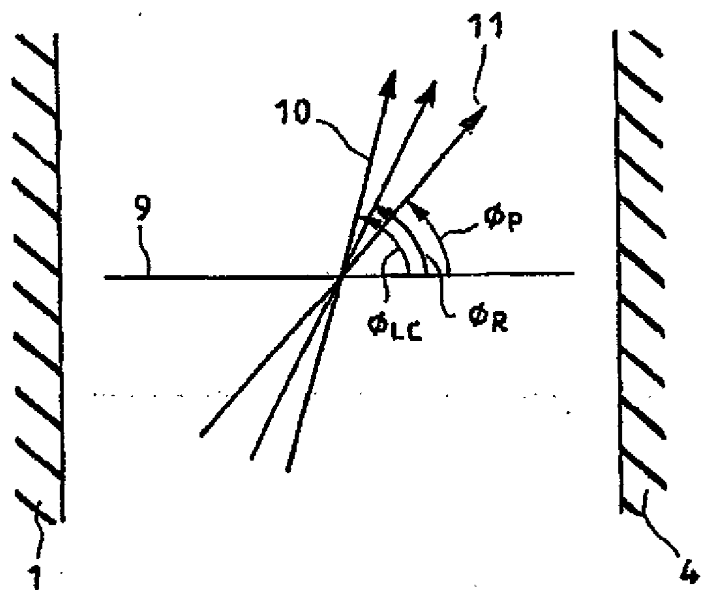


FIG. 3(a) FIG. 3(c)

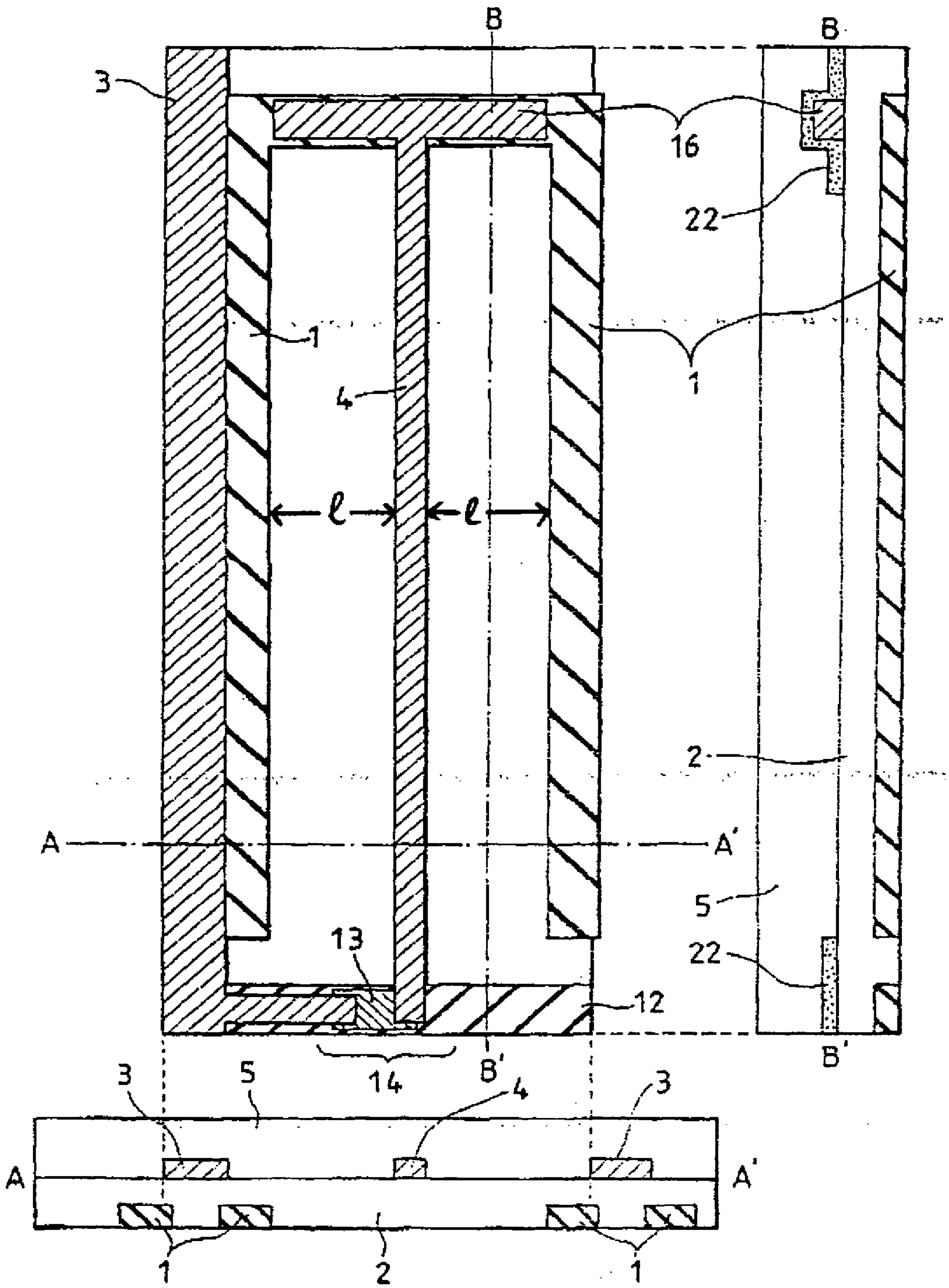


FIG. 3(b)

FIG. 4

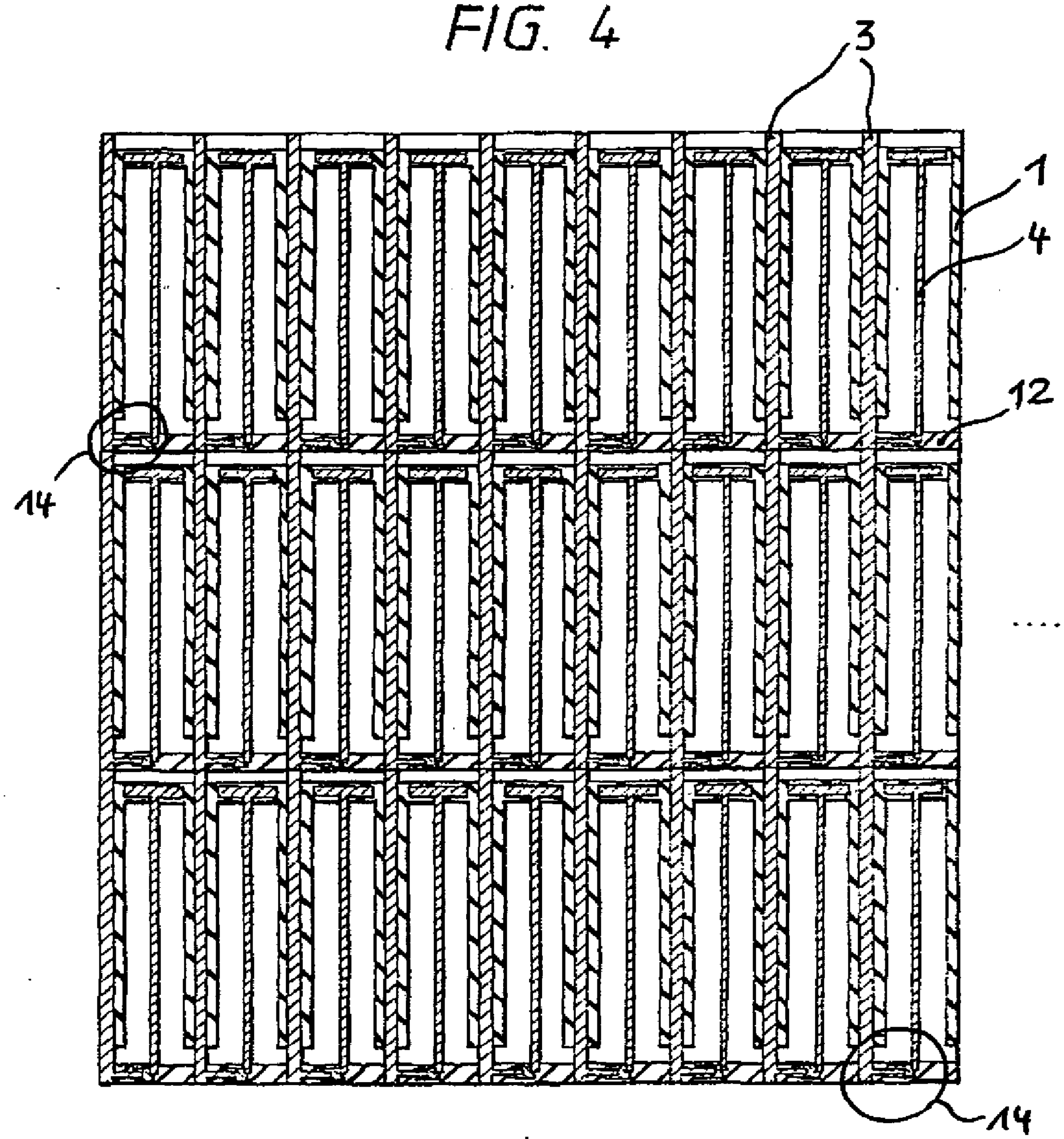


FIG. 5

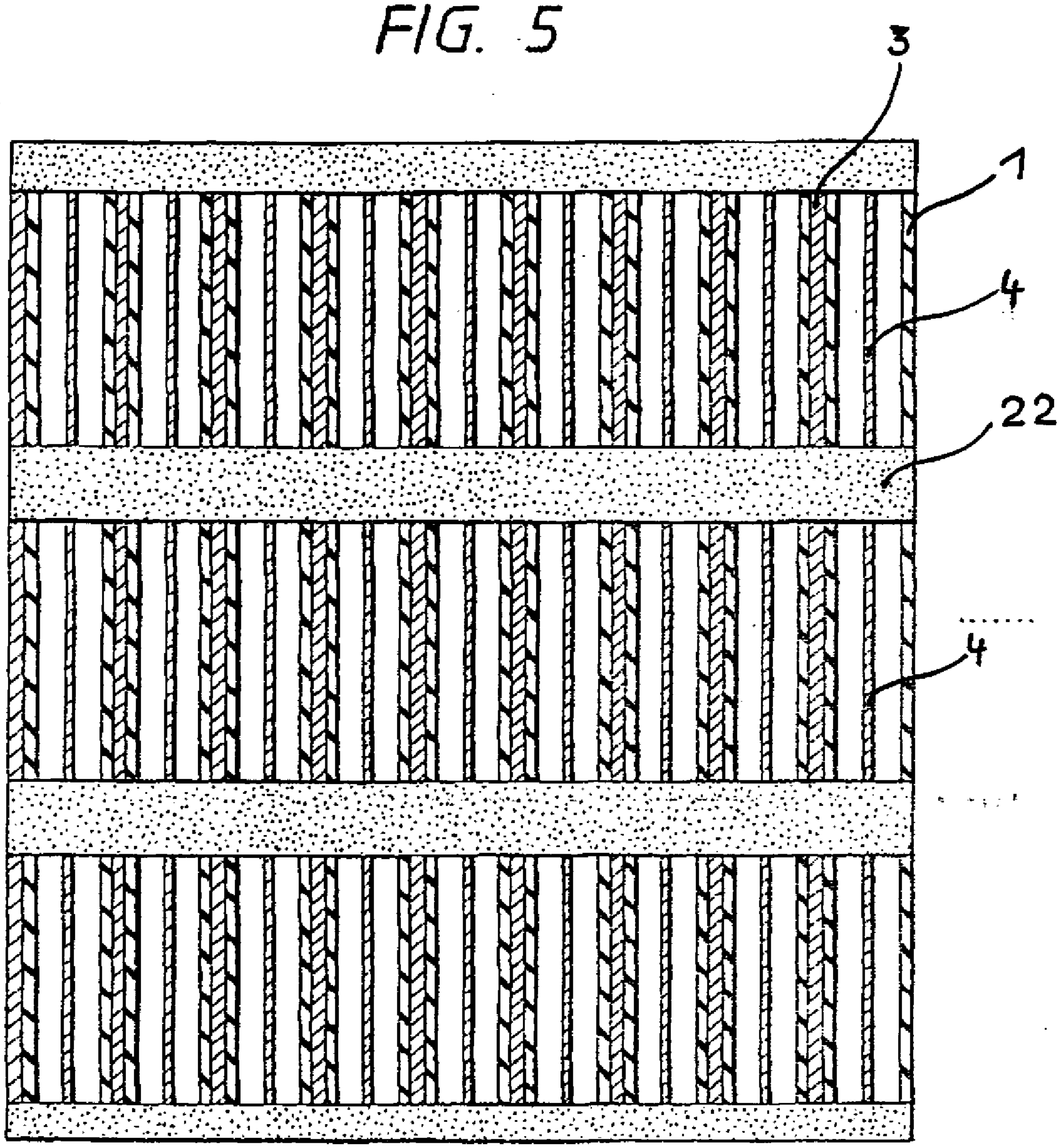


FIG. 6

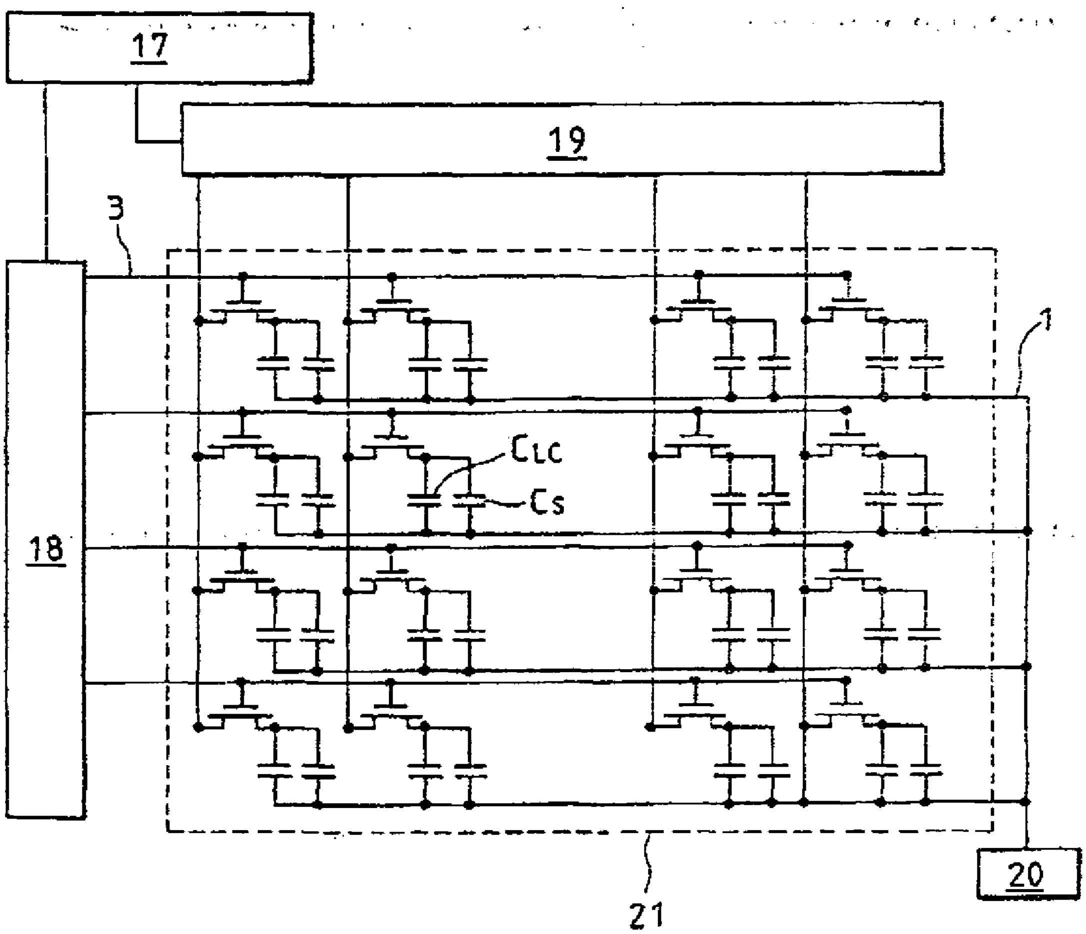


FIG. 7(a)

FIG. 7(b)

FIG. 7(c)

FIG. 7(d)

FIG. 7(e)

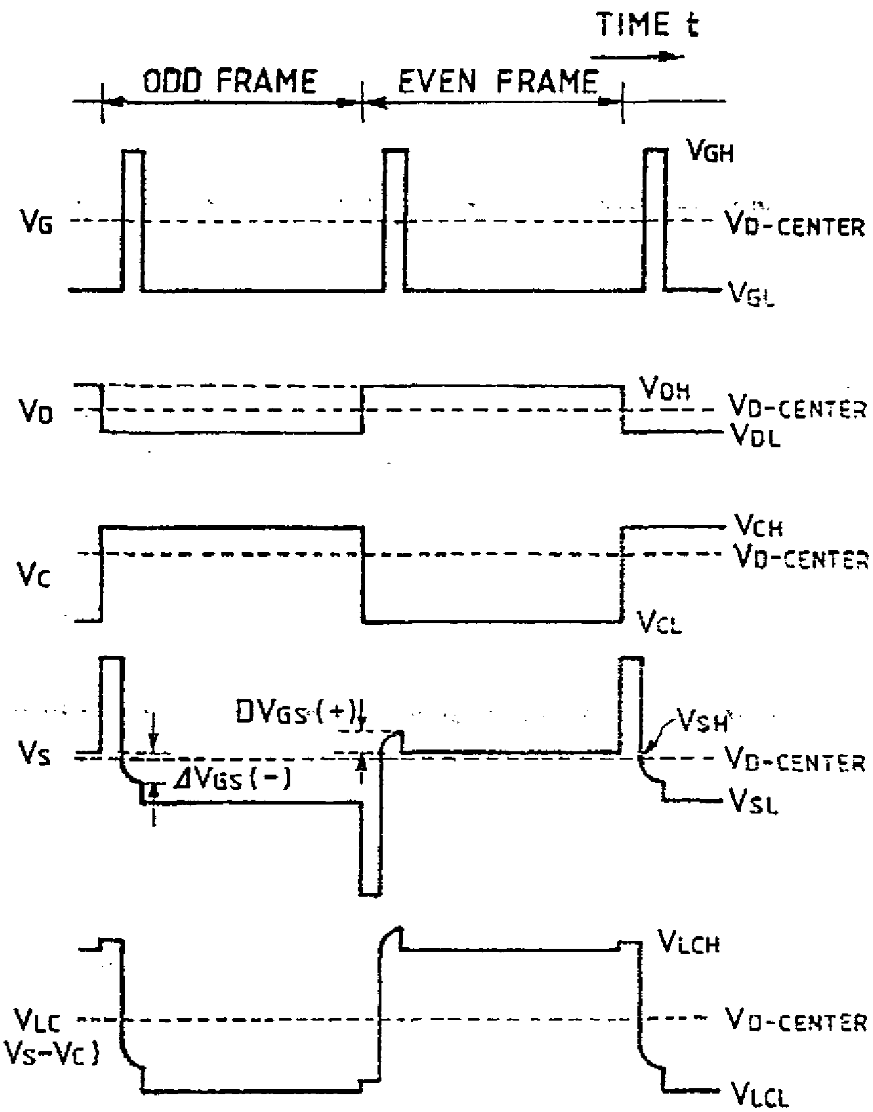


FIG. 8

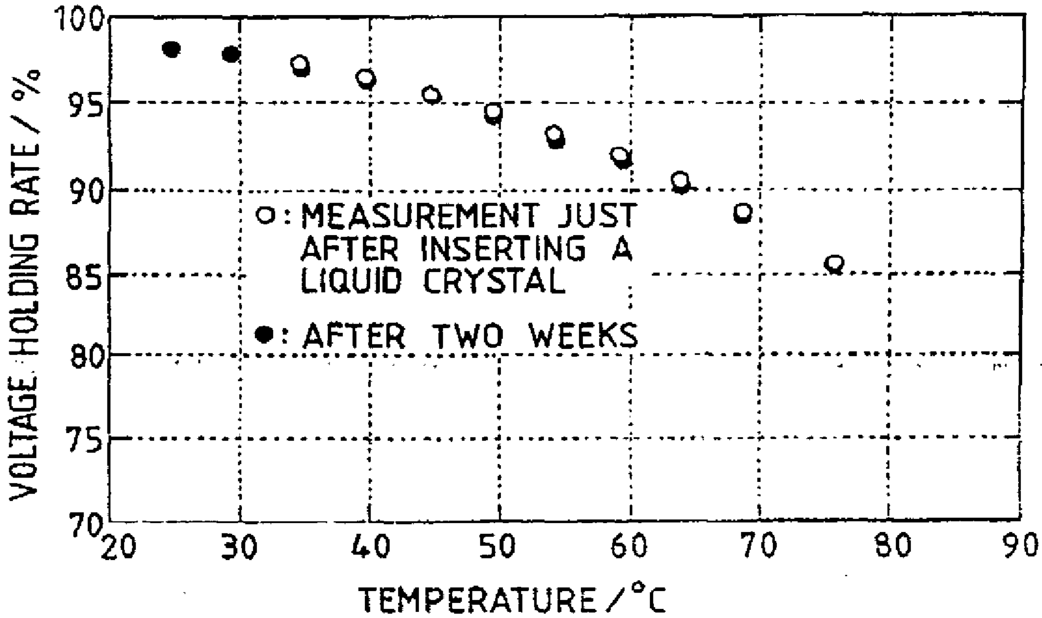

100
95
90
85
80
75
70
20
30
40
50
60
70
80
90
VOLTAGE HOLDING RATE / %
TEMPERATURE / °C
○ : MEASUREMENT JUST AFTER INSERTING A LIQUID CRYSTAL
● : AFTER TWO WEEKS

FIG. 9

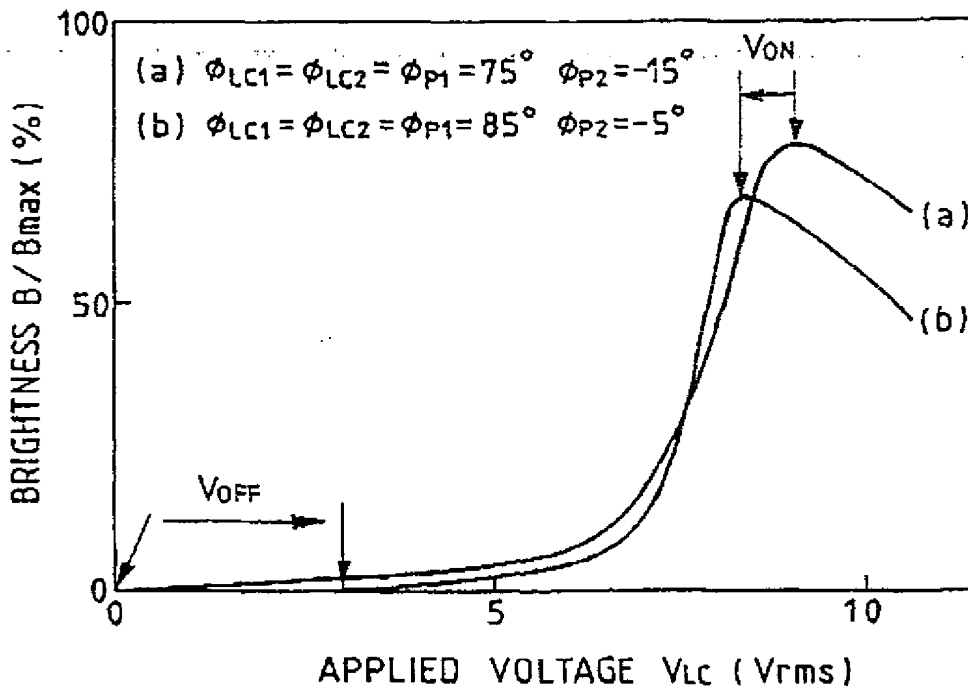

100
50
0
0
5
10
BRIGHTNESS B / Bmax (%)
APPLIED VOLTAGE VLC (Vrms)
(a) ΦLC1 = ΦLC2 = ΦP1 = 75° ΦP2 = -15°
(b) ΦLC1 = ΦLC2 = ΦP1 = 85° ΦP2 = -5°
VON
VOFF
(a)
(b)

FIG. 10

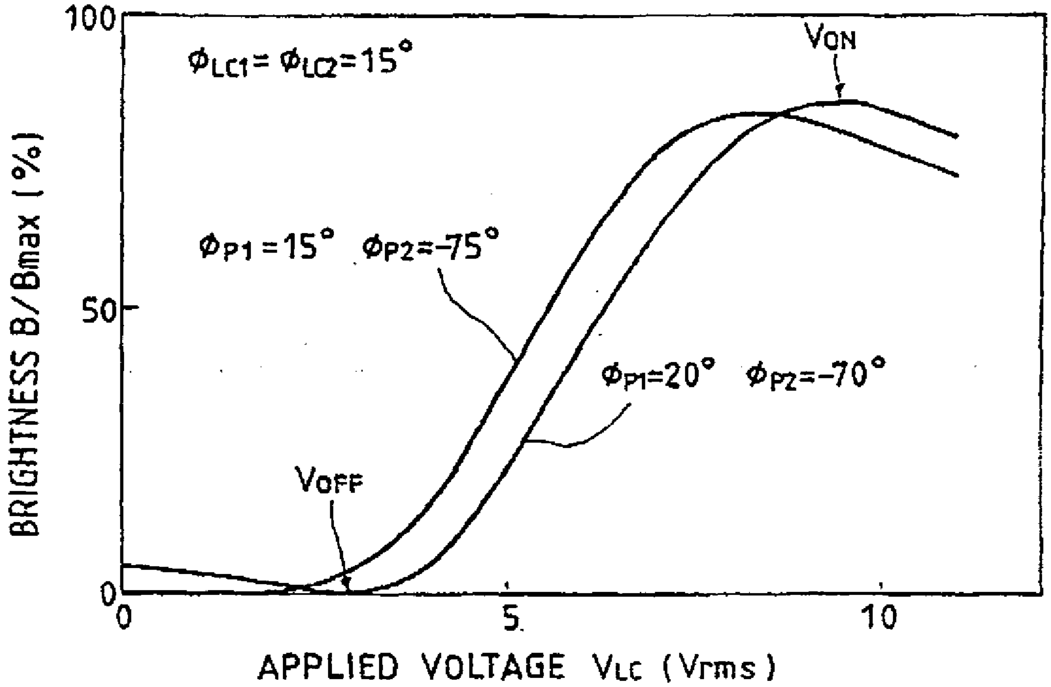

100
50
0
0
5
10
BRIGHTNESS B/Bmax (%)
APPLIED VOLTAGE VLC (Vrms)
ΦLC1= ΦLC2=15°
VON
ΦP1 =15° ΦP2=-75°
ΦP1=20° ΦP2=-70°
VOFF

FIG. 11

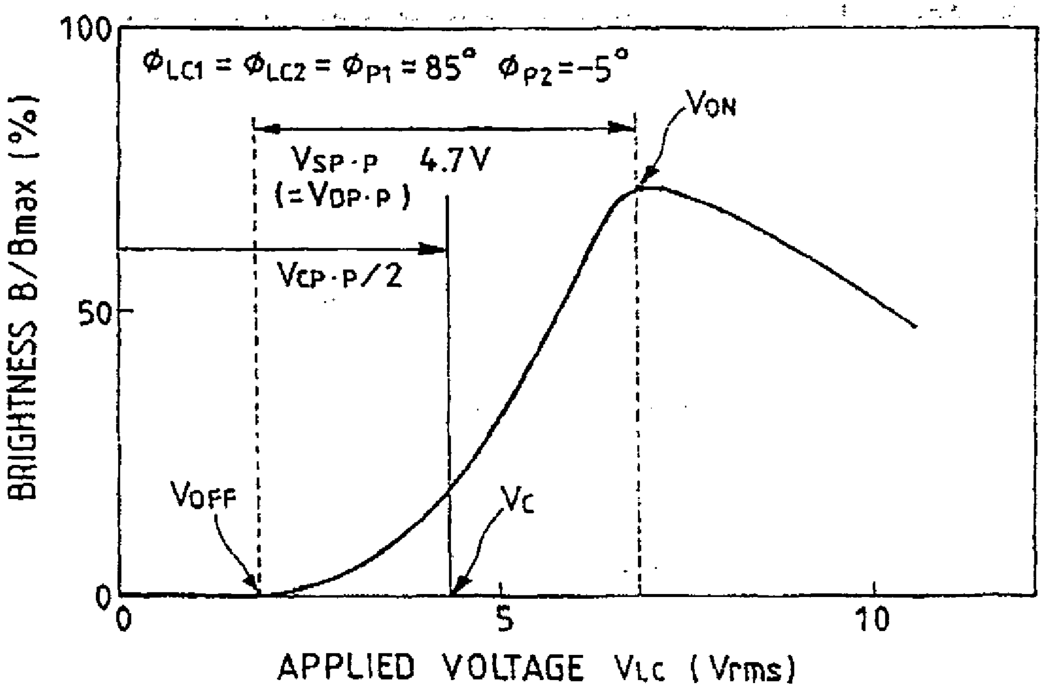
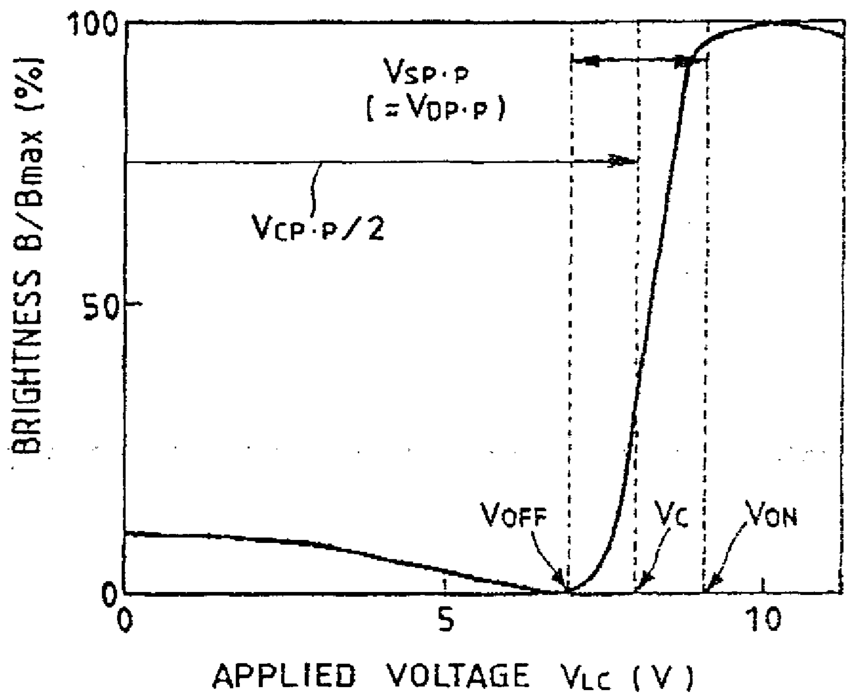

100
50
0
0
5
10
BRIGHTNESS B/Bmax (%)
APPLIED VOLTAGE VLC (Vrms)
ΦLC1 = ΦLC2 = ΦP1 = 85° ΦP2=-5°
VON
VSP·P 4.7V
(=VOP·P)
VCP·P/2
VOFF
VC

FIG. 12


100
50
0
BRIGHTNESS B/Bmax (%)
VSP·P
(= VDP·P)
VCP·P/2
VOFF
VC
VON
0
5
10
APPLIED VOLTAGE VLC (V)